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(54) PERIMETER SURVEILLANCE SYSTEM USING LEAKY COAXIAL CABLES

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A location and ranging system using a pair of leaky coaxial cables to detect targets along a prescribed route. When used as a security surveillance system an intruder is treated as the target and the prescribed cable routing is the perimeter of the protected area. The cables are mounted parallel to each other with a separation several orders of magnitude larger than their outer diameter. A transmitter is connected to one of the cables to propagate pulses of energy therealong. The presence of a target (any body which reflects or absorbs radio frequency energy) alters the coupling between the cables and, hence, provides a change in the return signal to a receiver connected to the other cable. This change in signal is processed digitally to discriminate between legitimate targets and very slow environmental changes and very high speed changes due to undersirable targets such as birds. A switching system is provided whereby each cable may be alternately connected to the transmitter and receiver thereby providing both detection of fault location and sufficient redundancy for continued operation.

This invention relates to a location and ranging system useful as a surveillance system for enclosed areas and, in particular, to such a system using a pair of leaky coaxial cables, one connected to a transmitter and the other to a receiver.

It is well known that there is a requirement for detecting unauthorized movement either entering into, or departing from, large enclosed areas such as prisons, airports, warehouses, freight yards and defence installations. The numerous types of apparatus presently employed in these applications all have serious disadvantages, especially for long perimeters (in excess of one mile) during adverse environmental conditions. Heavy rain or snow conditions can disable most optical systems based upon photoelectric sensors. Pressure sensitive devices can be ineffective in cold climates due to the penetration of frost. Both acoustic and seismic sensors are prone to false alarms due to gusts of wind or the proximity of vehicular traffic.

A number of perimeter protection systems are based upon the disturbance of electro-magnetic fields. Some systems rely upon the change of capacitance between two sensing wires. Others rely upon the change of impedance of a two wire transmission line due to the presence of an intruder. Most of these systems have relatively poor sensitivity because they attempt to detect very small changes in a large quantity which usually is a function of the physical deployment of the sensor. This can result in false alarms due to vibration, rain, snow or variations in temperature and humidity.

The use of coupled transmission lines together with digital processing can overcome most of these shortcomings. In the past, a system based upon coupled strip lines has been proposed. In that system, the transmission lines were

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separated by a fraction of an inch and detection of an object (a wheel of a vehicle or a shoe on a human foot, for example) occurred when the presence of the object caused a change or distortion in the electro-magnetic field coupling pattern. Due to the close proximity of these transmission lines, the zone of protection in such systems is very limited. In addition the construction and installation of these strip lines can be very cumbersome.

The present invention provides a significant zone of protection over long perimeters and, to this end, employs a pair of leaky coaxial cables surrounding the area to be protected. These cables are typically separated by several feet and can be mounted on a perimeter fence or below the perimeter surface. A pulse transmitter is connected to one of the cables and a receiver to the other. The presence of an intruder (a person or metallic object) alters the coupling between the cables and, hence, provides a return signal to the receiver. This change in the return signal is processed to provide target discrimination before an alarm is sounded.

The invention will now be described in greater detail with reference to a specific embodiment shown in the drawings in which:

Figure 1 is a schematic diagram of a surveillance system in accordance with the invention;

Figure 2 shows a display useful with the system of Figure 1;

Figure 3 shows types of leaky coaxial cable useful in the system of Figure 1;

Figure 4 shows the zone of detection in a plane perpendicular to the cables; and

Figure 5 shows examples of the manner in which the cables can be installed.

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Description of the preferred embodiment

Referring to Figure 1 two leaky coaxial cables 10 and 11 are arranged around the periphery of an area 12 to be monitored. A switching arrangement, shown schematically at 13, selectively connects matched loads 14 and 15 to a termination of each cable, a transmitter 16 to one of the cables and a receiver 17 to the other. A radio frequency (RF) processor 18 is connected to the transmitter 16 and the receiver 17. This RF processor is a signal detector such as a synchronous detector. The processed signal from RF processor 18 is connected to a digitizer 19. The digitized return is further processed by the filters 20, 21 and 22 and then fed to a threshold detector 23. An alarm 24 and a display unit 25 are connected to threshold detector 23.

Considering switch 13 to be connected as shown in full lines, the mode of operation of the system will now be described. Transmitter 16 sends a pulse of energy down cable 11 causing a travelling surface wave to propagate therealong. A portion of this travelling wave is coupled into cable 10 and returned to the receiver. The return signal is a function of the coupling factor between the sensor cables during the propagation of the pulse along the cable length. The electromagnetic field produced by cable 11 is altered by an intruder adjacent the cables, hence modifying the coupling factor and producing a change in the return signal. The processor 18 senses this change and translates the time delay between the onset of the pulse on cable 11 and the return of the change on cable 10 into the distance of the intruder from the cable end.

With the switch in the dotted line position (position B) the transmitted pulse is sent along cable 10 and the return signal is measured on cable 11. Under normal operations this provides redundant information to that obtained while the switch is in position A. However, should either or both cables be cut the combination of pulses on 10 and 11 would maintain

complete perimeter surveillance as well as exactly locating the point of discontinuity. Thus, both fault detection and information as to fault location are provided together with redundancy for continued operation.

In applying this system to very long perimeters, it will be necessary to insert amplifiers along the cable length as indicated at 26. The number of amplifiers required is proportional to the cable attenuation factor and hence is a function of the cable characteristics. Since the signals of interest, whether transmitted or received, always travel anticlockwise in cable 11 and clockwise in cable 10, only uni-directional amplifiers are required.

The processing of the return signal involves both analog and digital techniques. The analog processing implemented in processor 18 is basically an RF detector circuit which operates on the return signal. The result of this processing is an analog signal which describes the profile of the cable return. An intruder causes this profile to change at a point in time which corresponds to the location of the intruder along the sensor length.

The actual discrimination and detection of the intruder is preferably achieved by digital processing. The digitizer 19 derives a sequence of numbers which are proportional to the average magnitude of the cable profile signal over a sequence of time intervals which correspond to a sequence of cable segments. As a specific example, a five thousand foot perimeter may be considered as a sequence of five hundred ten foot cable segments which would require a sequence of five hundred numbers to describe the profile. This profile is completely updated periodically. If one particular number changes significantly with each update, it is assumed that an intruder is approaching or leaving the cable sensor at the cable segment corresponding to the particular cable profile number. In the preferred

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embodiment two low pass digital filters, 20 and 21, are used to process each of the profile numbers. This eliminates alarms due to very slow environmental changes and very fast changes such as caused by flying birds. For example, the time constant X for filter 20 may be five minutes and the time constant Y for filter 21 may be ten milliseconds. Hence any changes which occur slower than ten milliseconds and faster than five minutes will result in a difference which entered into a third low pass filter 22. The time constant Z of this third filter is adjusted to provide integration of the difference signal. The output of this filter is passed through a threshold detector 23. Hence any number describing a segment of the cable profile which changes within the band pass of the intrusion sensor will be detected. This is then used to trip alarm 24 and drive display unit 25.

It will be realized that there are a plurality of low pass filters 20, 21 and 22, one for each number in the sequence mentioned above. Since the filters are digital, the function of each may be performed by a single word in a digital storage arrangement and, hence, no undue complexity results. Similarly there is a plurality of threshold detectors 23, one for each number in the sequence. The alarm 24 and display unit 25, however, are common to all the numbers, only a single one of each being provided.

Figure 2 relates to a display suitable for use with the described system. A plan view 30 of the protected area is superimposed upon the face of a cathode ray oscilloscope 31. The co-ordinates of the cable sensor relative to this plan view are stored. When an intruder approaches the sensing cables a change is detected which trips an audible alarm and defines the location as a distance along the cable length. This information is then translated into the location of the intruder as described on the oscilloscope. A symbol 32 is

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then generated on the display at the point of intrusion. In response to the condition, the operator can turn off the audible alarm and check the location to determine the validity of the alarm. Once the intruder has been successfully located, the operator can remove the symbol from the display.

This system can provide a number of very desirable operating features. Multiple intruders at various points on the perimeter can be located simultaneously. Multiple intruders at a single point of entry may also be detected and displayed by a flashing symbol. Intruders passing through controlled entrances may be masked out in the digital processing. The optional feature of allowing authorized entry can be provided by means of transponders and special purpose processing and masking techniques.

Various types of leaky coaxial cable suitable for use in the system of the present invention, are shown in Figure 3. These cables are similar to ordinary coaxial cables with outer conductors modified to allow energy to be released from the cable. Depending upon the design of the particular cable, the energy that is released can propagate in either a surface wave or leaky wave mode or a combination of both modes. In general terms, the surface wave mode electric field strength decays more rapidly in a radial direction from the cable than for a leaky wave mode. Hence, the selection of the cable type is an important factor in determining the radial range of the sensor to meet a specific application.

The cables of Figures 3(a) and 3(d) have continuous slots but the latter, sold under the trade mark CERT ®, includes a further spiral wire as a radiating element. The cables of Figures 3(b), 3(c) and 3(e) have spaced apertures of different form. That of Figure 3(b) is sold under the trade mark RADIAX ®. The cable shown in Figure 3(c) has a loosely braided shield and that shown in Figure 3(e) has slots

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spaced at intervals of about 1 foot.

There are a number of design criteria governing the type of RF pulse generated. The frequency of operation for typical leaky coaxial cables is from 30MHz to 400MHz. A carrier frequency should be selected within this band which avoids any local interference. In this system, any decrease in pulse width generally improves the resolution at the expense of bandwidth. Any increase in bandwidth, however, increases noise and hence false alarm rate. For example cited (a 5000' perimeter), a pulse width of fifty nanoseconds and a carrier frequency of 150MHz is preferred.

The zone of protection provided by the cable sensors is illustrated in Figure 4. In free space, the zone would be an ellipse 40 with foci at the cables 41. By separating the cables, the area of the ellipse increases, leading however to greater sensitivity to environmental noise. In adapting the system to any particular application the parameters of cable type, power level, frequency of operation, pulse width and cable separation are all available for adjustment. In the example cited, the zone of protection would have a major axis "a" and minor axis "b" of 15 feet and 10 feet respectively on a human intruder.

The installation of the leaky coaxial cables is reasonably simple. Different sensor installations are illustrated in Figure 5. Figure 5a shows how the cables may be used in conjunction with a vertical fence. Figure 5b illustrates an installation below the surface typically at a depth of 1-2" and Figure 5c illustrates cables spaced horizontally above the surface, thereby providing a wider zone of protection than vertical spacing.

While the foregoing invention has been described in connection with an intrusion detection system, it will be clear that the system has a number of other applications. For

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example, the leaky cable sensor can be used to locate vehicles on airport manoeuvering surfaces or for the location of vehicles on a rapid transit system and to meet other requirements for the location of objects over long prescribed paths under adverse environmental conditions. Various changes in the exact structure of the preferred embodiment will be obvious to those skilled in the art. For example, other types of display units which can be used include plasma displays and light emitting diodes.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A detection system for locating targets which reflect or absorb electro-magnetic energy comprising, first and second leaky coaxial cables extending along a prescribed path and spaced from another a distance greater than an order of magnitude larger than their outside diameter, a transmitter connected to one of said cables and a receiver connected to the other to receive a signal derived from the transmitter, whereby a target alters the coupling between the cables and means processing the received signal to determine the location of the target.

2. A system as set out in claim 1, further including switching means selectively connecting said transmitter and receiver to said cables whereby the direction of signal propagation around an area can be reversed.

3. A system as set out in claim 1 wherein said processing means includes a synchronous detector.

4. A system set out in claim 3 wherein the signals from said synchronous detector are digitized and said processing means further includes digital filter means having a bandwidth between about .03 hz and 100 hz.

5. A system as set out in claim 4 including a further digital connected to the output of the digital filter means to provide approximate integration.

6. A system as set out in claims 5 further including a threshold detector responsive to the output from said further digital filter to actuate alarm and display means.

7. A system as set out in claim 1 wherein said means processing the received signal includes a digital processing system, comprising a digitizer, a plurality of low pass filters

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and a plurality of threshold detectors, the digitizer computing a sequence of numbers to represent the average magnitude of the recieved signal over a sequence of time intervals and three low pass digital filters are provided for each number in the sequence, the time constants of the first and second low pass filters being adjusted so that the difference in their outputs discriminates between very slow and very fast changes in the received signal, said difference being further filtered by the third low pass filter to provide approximate integration, the threshold detector associated with each number being used to determine the presence of a change in the received signal associated with a target in which the location of the target is determined from the particular number in the sequence for which the threshold detector is energized.

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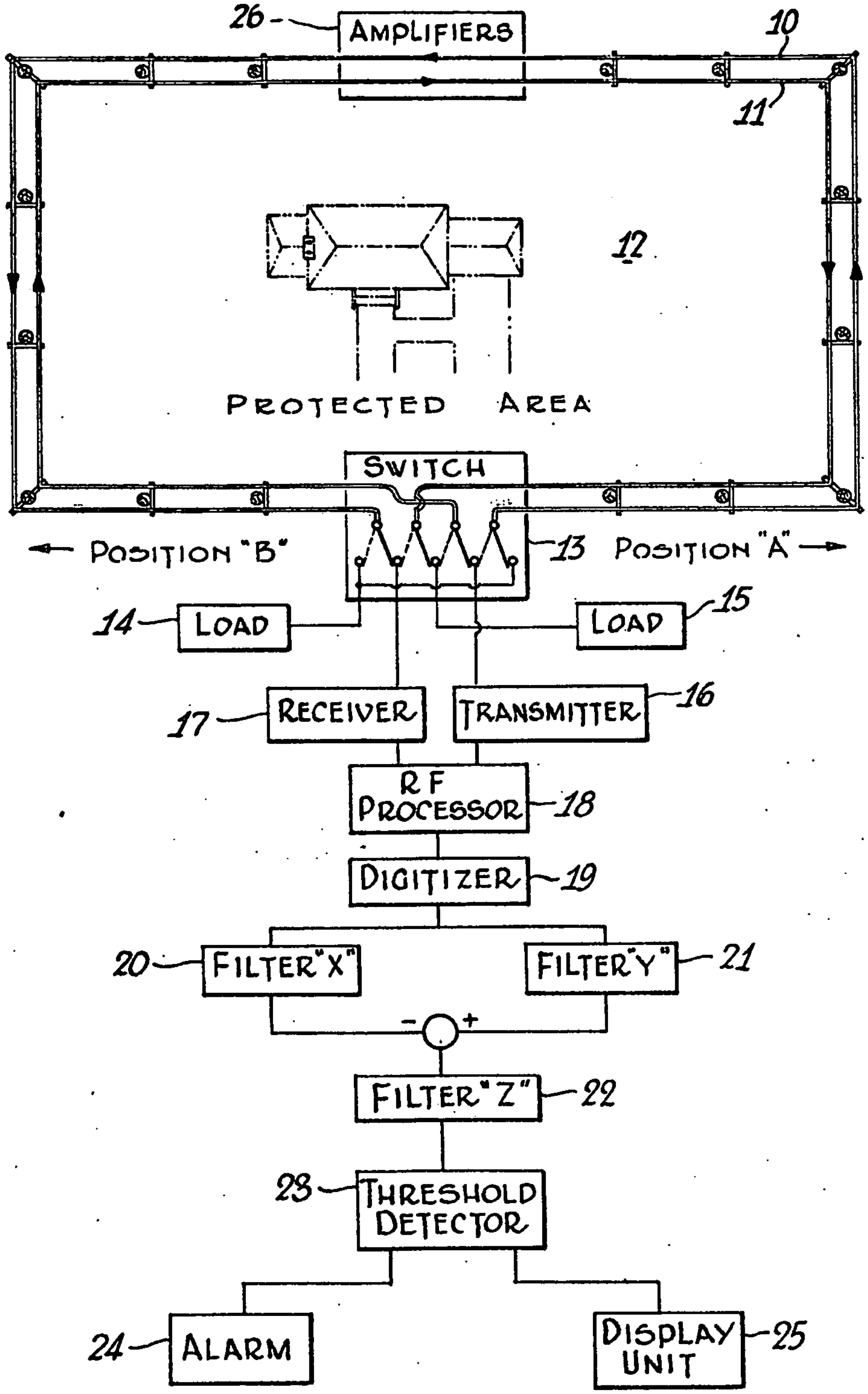

-Fig-1-

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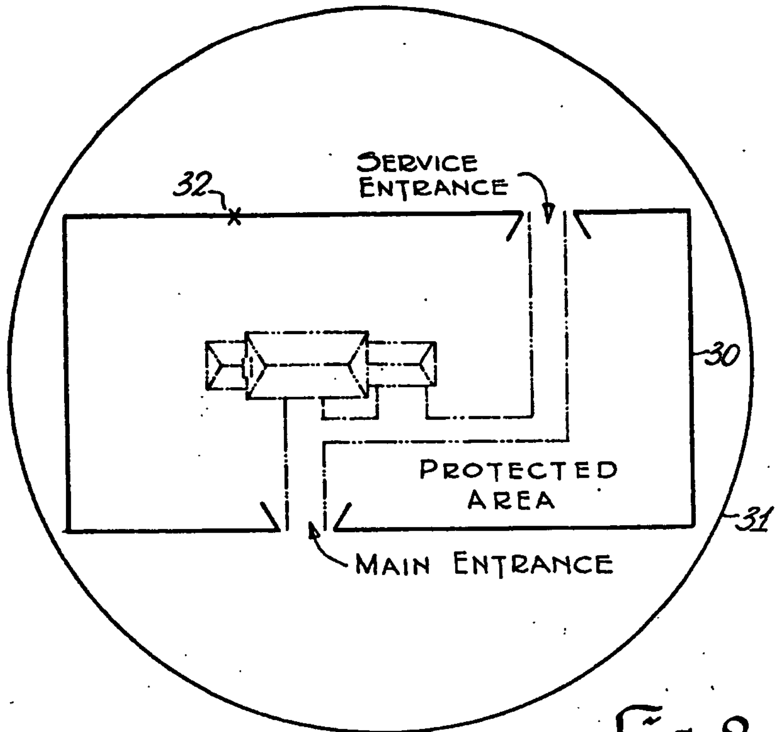
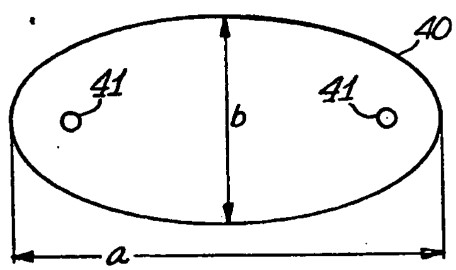
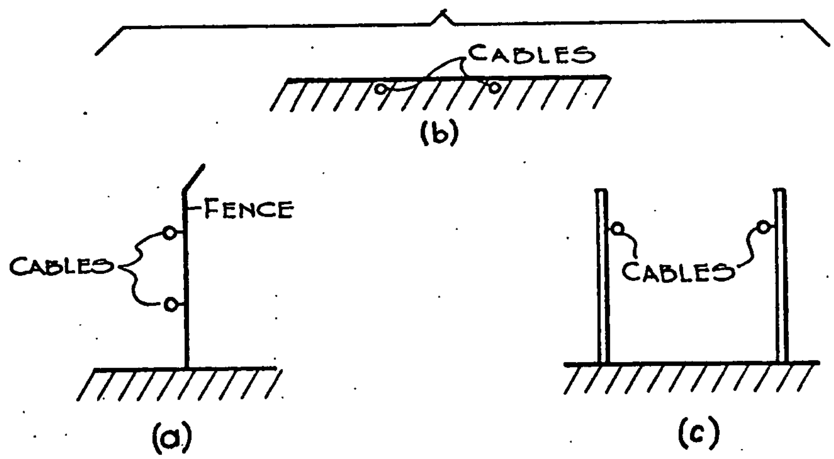


-Fig-2-



-Fig-4-

-Fig-5-



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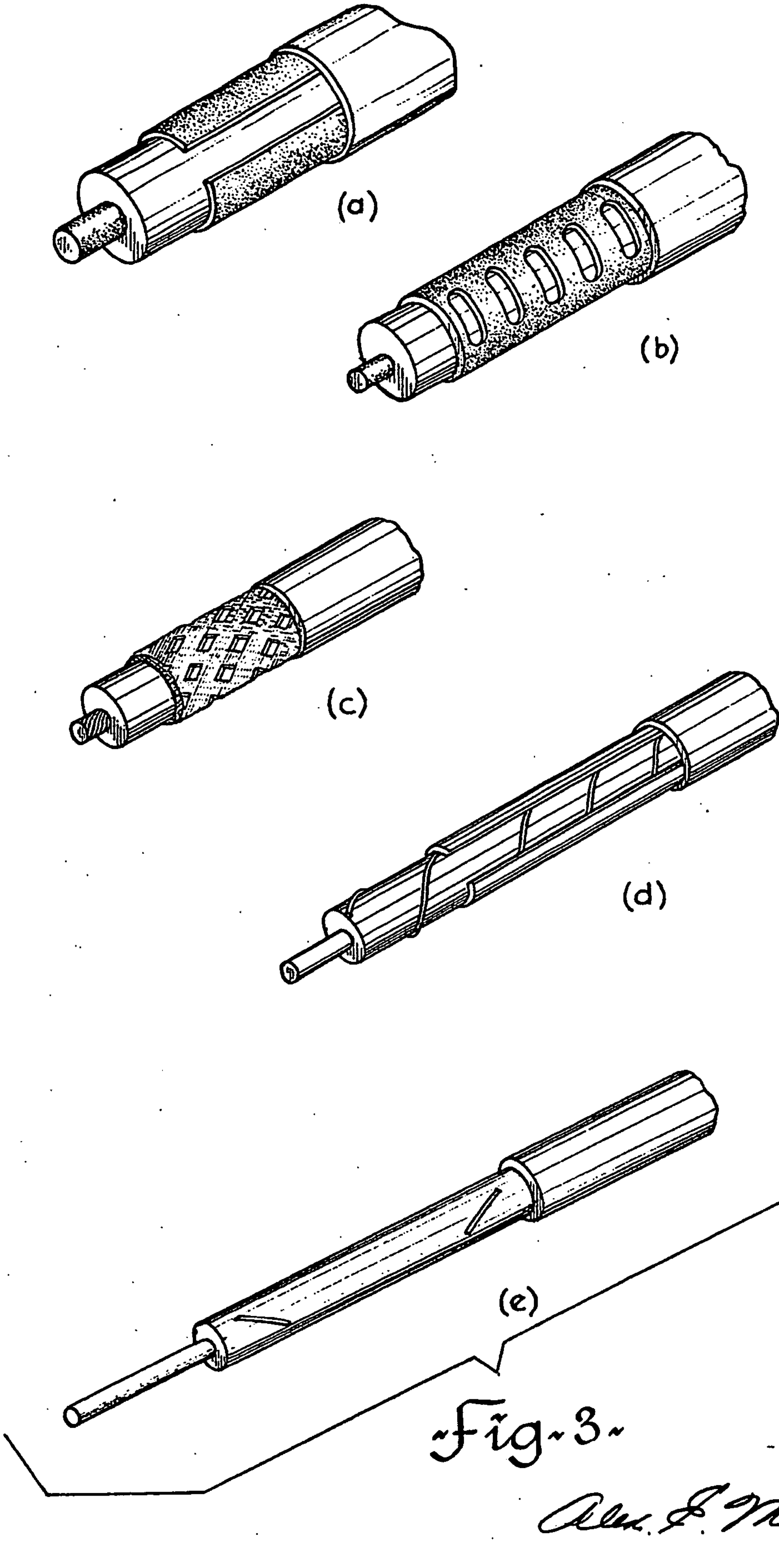

-Fig-3-

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